Exploring How to Use Scenarios to Discover Requirements

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Abstract

This paper investigates the effectiveness of different uses of scenarios on requirements discovery using results from requirements processes in 2 projects. The first specified requirements on a new aircraft management system at a regional UK airport to reduce its environmental impact. The second specified new work-based learning tools to be adopted by a consortium of organizations. In both projects scenarios were walked through both in facilitated workshops and in the stakeholders' workplaces using different forms of a scenario tool. In the second project scenarios were also walked through with a software prototype and creativity prompts. Results revealed both qualitative and quantitative differences in discovered requirements that have potential implications for models of scenario-based requirements discovery and the design of scenario tools.

1. Different Scenario Uses

Scenarios are sequences of events with a narrative structure [Alexander & Maiden 2004]. They are simple, human things [Alexander & Maiden 2004], and walking through them is one of the more effective means by which stakeholders discover requirements. Studies have reported stakeholders walking through different types of scenarios, from simple stories to surface new requirements [Carroll

2000] to system simulations to discover emergent system properties [Haumer et al. 1999]. However, despite reported successes, we still lack data with which to determine what are the more effective uses of scenarios for discovering requirements. This paper reports results from 2 scenario-driven processes to discover requirements for an air traffic management system called VANTAGE (*Validation of Network-Centric, Technology Rich ATM System Guided by the Need for Environmental Governance)* and a system to support work-integrated learning in organizations called APOSDLE (*Advanced Process-Oriented Self-Directed Learning Environment*).

ART-SCENE is a software environment for discovering and documenting stakeholder requirements [Maiden 2004] by walking through scenarios that are automatically generated from use case specifications. We run what we call *scenario workshop walkthroughs* for same-time same-place discovery of requirements using the desktop version of ART-SCENE [Maiden 2004]. A workshop is a structured meeting that is ran by a trained facilitator to ensure effective stakeholder input to the meeting. The facilitator drives the walkthrough process whilst a scribe documents requirements and scenario changes in ART-SCENE. Similar uses of scenarios are reported in [Gottensdeiner 2004, Uchitel et al. 2004]. Stakeholders walk through one ART-SCENE-generated scenario displayed to them on a large screen. In the VANTAGE project we ran 4 *scenario workshop walkthroughs* to discover requirements.

Walking through software prototypes and scenarios together has been shown to improve requirements completeness [Weidenhaupt et al. 1998]. In the APOSDLE project a first prototype of the work-integrated learning system had already been developed. Therefore, we ran 8 *scenario workshop walkthroughs* that walked through ART-SCENE scenarios and the APOSDLE prototype together. Each *scenario workshop walkthrough* was supplemented by results from an earlier creativity workshop held in the project [Jones et al. 2008] that provided additional vision, requirements and design features for future versions of the APOSDLE system.

However bringing stakeholders together in workshops can be difficult and time-consuming, whilst removing them from their workplace can miss important contextual triggers for requirements. One alternative is to walk through scenarios in the workplace using mobile technologies. Previously we developed a version of ART-SCENE called the Mobile Scenario Presenter (MSP) to run on a Personal Digital Assistant (PDA). Evaluations of the MSP [Maiden et al. 2006, Maiden et al. 2007] revealed that it could be used to discover requirements in the workplace, however analysts found it difficult to document requirements using the stylus when moving and/or communicating with the observed stakeholders. Therefore we also walked through 1 ART-SCENE scenario in the VANTAGE project and 4 different ART-SCENE scenarios in the APOSDLE project in the workplace to provide empirical data about their effectiveness. We call these walkthroughs *scenario workplace walkthroughs*.

We used data from the *scenario workshop walkthroughs* and *scenario workplace walkthroughs* in the VANTAGE and APOSDLE projects to answer 3 research questions:

Q1 Can a *scenario workshop walkthrough*, supported with software prototypes and design features, trigger a larger number of requirements than the walkthrough of the scenario on its own?

Q2 Can a *scenario workplace walkthrough* trigger requirements that might not be discovered with a *scenario workshop walkthrough*?

Q3 Can a *scenario workplace walkthrough* trigger a larger number of requirements than an equivalent *scenario workshop walkthrough*?

The first research question Q1 explored whether supplementing scenarios with design knowledge in the software prototypes and creativity prompts would increase the number of requirements generated. We distinguished between Q2 and Q3 to investigate whether *scenario workplace walkthroughs* generated different requirements from *scenario workshop walkthroughs*.

In the remainder of the paper section 2 reports the different uses of scenarios that were applied in VANTAGE and APOSDLE. Section 3 reports a model of scenario-based discovery that informs the 3 research questions. Sections 4 and 5 report results from the scenario walkthroughs to answer the research questions. Section 6 uses the results to answer the 3 research questions and explore their validity. Sections 7 and 8 present lessons learned for running future scenario walkthroughs and report related work. Section 9 outlines future research to improve scenario use in requirements processes.

2. ART-SCENE Scenario Walkthroughs

The VANTAGE and APOSDLE scenarios were generated and walked through using the ART-SCENE environment.

2.1 ART-SCENE Scenarios

The big idea that underpins ART-SCENE scenario walkthroughs is very simple – that people are better at identifying errors of commission rather than omission [Baddeley 1990]. From this general trend in human cognition for recall to be weaker than recognition, ART-SCENE scenarios in the ART-SCENE software environment offer stakeholders recognition cues in the form of automatically generated alternative courses. If the alternative course is relevant to the system being specified but not yet handled in the specification, then a potential omission has been identified, and ART-SCENE guides the analysts to specify and document the relevant requirements.

ART-SCENE automatically generates scenarios in 2 steps [Maiden 2004]. In the first it generates different normal course scenarios from ordering rules in the use case specification. Each different possible ordering of normal course events is a different scenario. In the second the algorithm generates candidate alternative courses, which are expressed as 'what-if' questions for each normal course event, by querying a database that implements a simple model of over 40 abnormal behaviours and states in socio-technical systems independent of the domain of interest. Some class hierarchies were derived from definitions of scenario concepts such as events and actions. Others were derived from error taxonomies in the cognitive science, human-computer interaction and safety-critical disciplines [Sutcliffe et al. 1998]. ART-SCENE allows specialization of these classes to selected domains such as air traffic management and learning, as reported in [Mavin & Maiden 2003].

ART-SCENE provides scenarios to stakeholders to recognize events and discover requirements in two ways – in *scenario workshop walkthroughs* and *scenario workplace walkthroughs*. Each is described in turn.

2.2 Scenario Workshop Walkthroughs

In *scenario workshop walkthroughs* stakeholders interact with one ART-SCENE component called the Scenario Presenter. Figure 1 depicts one scenario generated for VANTAGE and presented using the Scenario Presenter. A *scenario workshop walkthrough* typically lasts half a day [Maiden 2004]. A facilitator guides the stakeholders to recognise which scenario normal and alternative course events – what-if capabilities – the new system must handle. The facilitator then uses simple heuristics to discover one or more requirements that, if satisfied, will enable the system to avoid, respond to or mitigate the effects of the event. The scribe documents all requirements in ART-SCENE and links them to the scenario events that triggered them.

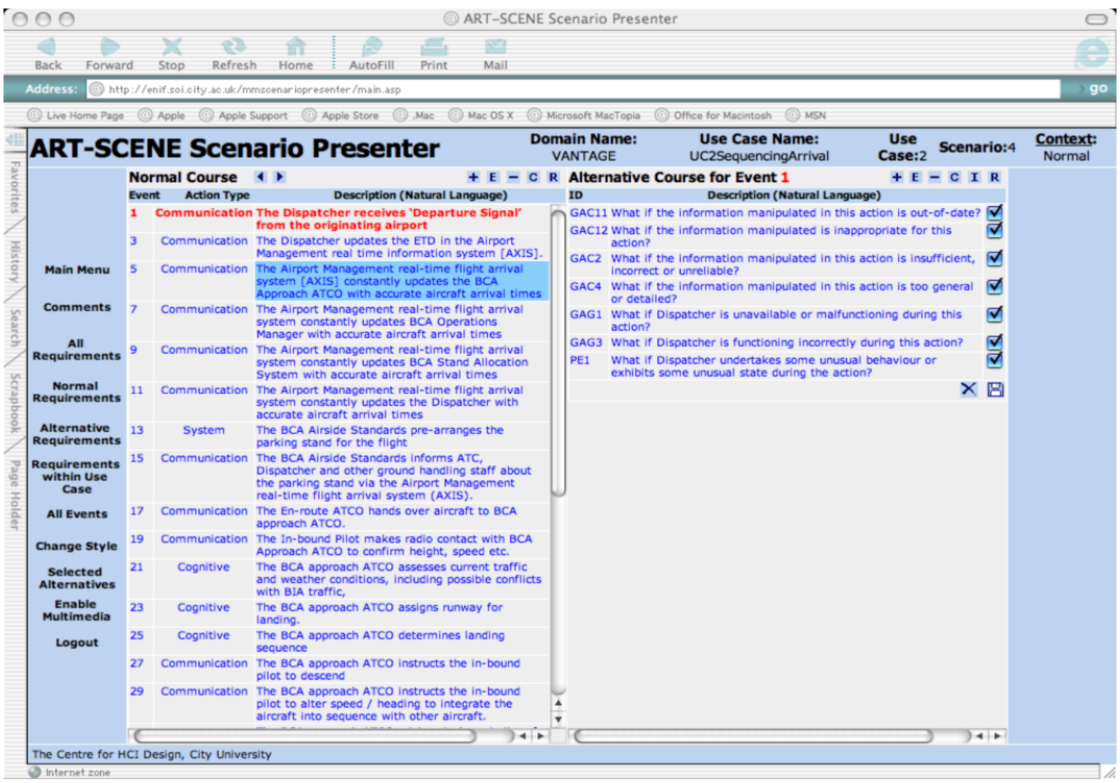

Figure 1. One VANTAGE scenario (*VA2 Approach/Arrival Sequence Control*) in the desktop version of ART-SCENE used during a *scenario workshop walkthrough.*

In a *scenario workshop walkthrough* the facilitator walks the stakeholders through an ART-SCENE scenario, but these scenarios can be supplemented with other artefacts. In APOSDLE we ran *scenario walkthrough workshops*, in which we walked through related design features of an existing work-integrated software prototype using an electronic whiteboard that stakeholders could manipulate directly by touch to sketch and document changes to supplement the requirements documented in ART-SCENE. We also searched for and presented results from an earlier creativity workshop [Jones et al. 2008] on a third display to reuse visions, requirements and design ideas that had been generated by stakeholders earlier in the requirements process. As a result, at any time during each workshop, stakeholders were interacting with the ART-SCENE scenario, existing software prototype and documented ideas from earlier activities.

However, one limitation of *scenario workshop walkthroughs* is that stakeholders need to take time out of their workplace to participate. As well as restricting access to stakeholders who might not have the time to participate, these sessions take place out of the workplace, thus potentially diminishing the effectiveness in the requirements discovery process [Zachos et al. 2005].

2.3 Scenario Workplace Walkthroughs

The MSP [Maiden et al. 2006] is a PDA-based ASP.NET web application that uses a mobile browser and wireless access to connect to server-side ART-SCENE scenario and requirements databases. The tool is optimized for Microsoft's Pocket Internet Explorer included with Microsoft's Pocket PC OS. The MSP allows its user to discover and document requirements systematically in the workplace using structured scenarios generated by ART-SCENE. The MSP user walks through scenarios of future system behaviour and observes current system behaviour at the same time. What-if capabilities – generated candidate alternative courses for each event – enable the user to follow up and ask questions about abnormal and unusual behaviour in different workplaces, thus leading to more complete requirements discovery. Figure 2 shows some normal and alternative course events of a second VANTAGE scenario, *VA4 On-stand Operations*, that we walked through using the MSP.

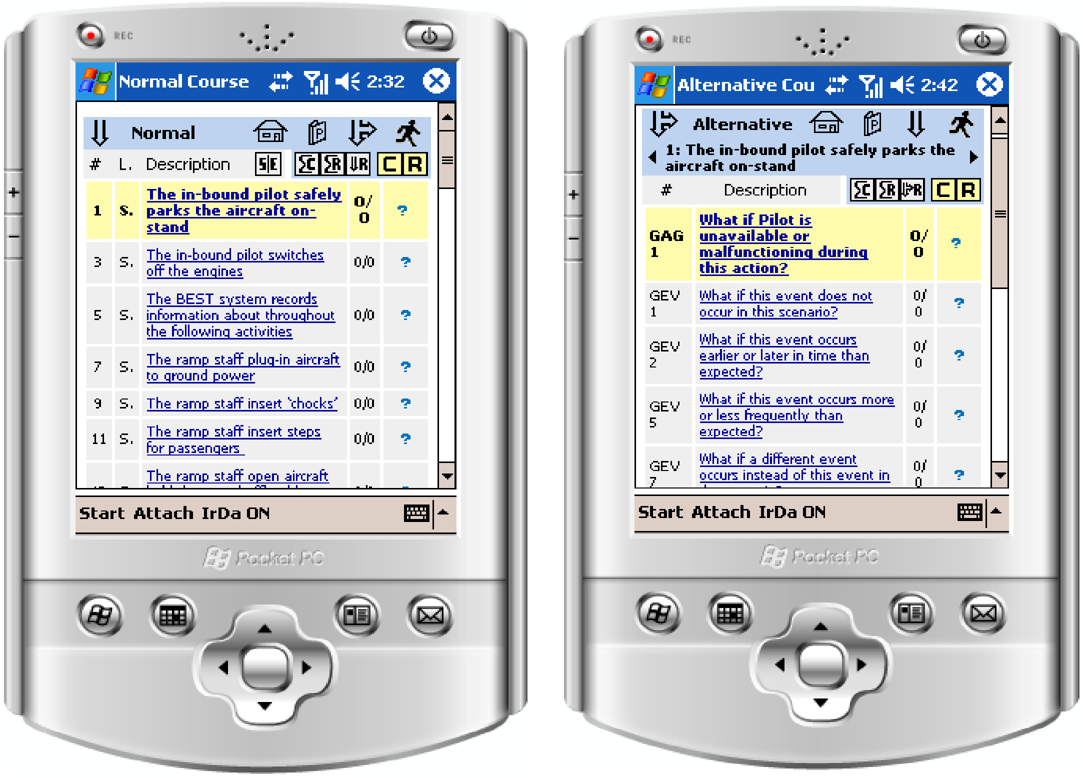

Figure 2. The VANTAGE scenario *VA4 On-stand Operations* in the MSP version of ART-SCENE used in a *scenario workplace walkthrough*.

One important enhancement to the MSP used in VANTAGE was audio recording of requirements. Earlier versions captured new requirements in typed form using the PDA stylus [9]. However this was less successful than expected due to the effort needed to type requirements. Therefore the reported *scenario workplace walkthroughs* took place with audio recording of spoken requirements. To deliver this capability the MSP implemented a new plug-in solution on top of the full-screen browser application. The solution was integrated into the menu of the full-screen browser. The capability could be started using one touch with the stylus once the plug-in solution was enacted. Audio files of generated requirements were stored using common file formats so that analysts could continue their work on the desktop ART-SCENE after synchronization. All created multimedia files were linked to the underlying MSP database using special IDs included in the filename.

Another change undertaken in VANTAGE and APOSDLE was the process of the *scenario workplace walkthrough*. In previous applications we replaced workshops with a two-stage process – one-on-one observations and fact gathering by a single analyst in the workplace followed by project-wide interpretation sessions using the desktop Scenario Presenter. However this procedure was problematic. A single analyst was not able to observe the workplace, navigate the scenario, communicate with stakeholders and document requirements using a stylus because earlier audio-recording features were too cumbersome to use [Maiden et al. 2006]. Therefore, in VANTAGE and APOSDLE, we introduced the two roles of facilitator and scribe. Whilst the scribe used the MSP to navigate between scenario events and to document requirements and comments, the facilitator observed the workplace, asked questions about it, and filtered the raw data to generate first-cut requirement statements, based on recognition cues provided by the MSP.

3. A Model of Scenario-Based Requirements Discovery

We investigated the scenario-driven requirements processes in VANTAGE and APOSDLE to answer the 3 research questions reported in section 1 about the effectiveness of different scenario walkthrough types. The questions were grounded in a logical task model that describes essential cognitive tasks that stakeholders undertake during a scenario walkthrough to specify a future system using tools such as the Scenario Presenter.

The model describes scenario-based requirements discovery as an iteration of tasks. Stakeholders read scenario event descriptions and recognize one or more as possible and to be handled by the system. Recognizing whether an event is *relevant* is an essential pre-requisite to discovering requirements. Because stakeholders are better at recognizing incorrect events rather than recalling missing ones, the model predicts that stakeholders will discover more requirements using scenario events that are presented to them to recognize as relevant than they will from unaided recall of such events. For each event recognized as possible, stakeholders generate one or more requirements.

We developed and validated the model for *scenario workshop walkthroughs* with tools such as the ART-SCENE Scenario Presenter. However, extending our scenarios, such as with prototypes, creativity prompts, and walking through scenarios in the workplace challenge assumptions behind the model. For example, software prototypes and creativity explicitly describe design knowledge with which to infer requirements about the new system, which might generate more requirements than simply recognizing unhandled events in a scenario. On the other hand, design decisions embedded in the software prototype might lead to more requirements that encapsulate design decisions and assumptions. Therefore we explored the effect of recognition cues from scenario events, software prototypes and creativity prompts to answer Q1 using data from the APOSDLE scenario walkthroughs. Likewise, walking through scenarios in the workplace might expose analysts and stakeholders to more event recognition cues. However the timing of these events cannot be controlled, thus making it more difficult for analysts to capture and specify new requirements. We also explored the effect of combined recognition cues from scenarios and the workplace and audio requirements recording techniques to answer Q2 and Q3 with data from the *scenario workplace walkthroughs*.

The types of dependent variable data that were used to answer the 3 research questions are listed in Table 1. The generated requirements data was drawn directly from ART-SCENE's scenario and requirements databases, and scenario walkthrough data was taken from observational notes recorded by the facilitator and scribe during the scenario walkthroughs.

Generated requirements data	Scenario walkthrough data
Total number of requirements generated in a scenario walkthrough	Duration of the scenario walkthrough
Requirements description text	Number of stakeholders presented in the scenario walkthrough
Assigned requirement type	
Scenario that triggered generation of the requirement	
Scenario event that triggered generation of the requirement	

Table 1. Types of data used to answer 3 research questions.

We did not investigate stakeholder perceptions about the walkthroughs and the scenarios due to difficulties capturing such data in the VANTAGE and APOSDLE projects. Stakeholders such as pilots and business consultants were simply not available to be debriefed at the end of sessions, and the availability of other stakeholders was restricted during both projects.

The next 2 sections report the scenario walkthroughs and results for the VANTAGE and APOSDLE projects respectively.

4. Walking Through Scenarios in VANTAGE

We walked through scenarios to discover requirements for VANTAGE Phase-1, a system to reduce the environmental impact of aircraft movements in and around airports. The two-year project, funded by the UK's Department of Trade and Industry, integrated new technologies into the operations of regional airports in the United Kingdom to reduce their environmental impact, measured as noise and gas emissions. Partners who include Thales and Qinetiq introduced new technologies at Belfast City Airport BCA.

We walked stakeholders through scenarios as part of RESCUE (*Requirements Engineering with Scenarios in a User-Centred Environment*), a scenario-driven requirements process [Maiden et al. 2004]. Prior to the walkthroughs the requirements team had discovered requirements for the new VANTAGE system using brainstorming sessions and a creativity workshop, and generated requirements automatically from *i** models. A use case model specified 20 core use cases that specified how the future VANTAGE-enhanced airport operations at BCA should behave during landing, taxiing, on-stand operations and take-off, as well as to support airport management such as producing daily flight schedules. Requirements on the VANTAGE system were associated with behaviour specified in the use cases. However, we still needed VANTAGE stakeholders, who included the BCA environmental manager, environmental experts, technology specialists, and airline pilots and operational staff, to discover complete requirements on VANTAGE using projections of future operations at BCA. This is where the scenario walkthroughs came in.

The scenario walkthroughs took place with real-world project constraints such as time and availability of stakeholders that could not be controlled in the walkthroughs without disrupting the project or invalidating its results. Therefore we adopted an action research approach, generating and analyzing data in context, taking care when drawing conclusions from the results.

4.1 The Scenario Walkthrough Schedule

We generated a scenario walkthrough schedule from the VANTAGE use case model. VANTAGE stakeholders prioritized the use cases for the potential of the specified behaviour to minimize environmental impact. Not surprisingly, given aircraft movements are the main source of noise and gas emissions, the priority use cases specified VANTAGE requirements on the arrival, turnaround and departure of an aircraft from the airport.

Time and resource constraints meant that only five use cases could be investigated. We set up the walkthrough schedule in Table 2 and used the ART-SCENE scenario generation algorithm to generate one scenario per use case.

Date	Scenario	Type of walkthrough
11/09/06	VA2: Approach/arrival sequence control	Workshop
11/09/06	VA3: Ground movement control arrivals	Workshop
17/10/06	VA1: Ground movement control departure	Workshop
17/10/06	VA11: Coordinate flight departures	Workshop
29/11/06	VA4: On-stand operations	Workplace

Table 2. VANTAGE scenario walkthrough schedule

We chose to run *scenario workshop walkthroughs* to walk through scenarios that describe aircraft movement, such as *VA2 Approach and arrival sequence control* and *VA11 Coordinate flight departures*. Not only were *scenario workplace walkthroughs* of such scenarios on the airport difficult (not to say dangerous!), but *scenario workshop walkthroughs* were tractable because representatives of stakeholders such as airlines (pilots and dispatchers), air traffic controllers and managers, the airport environment manager, and solution experts from VANTAGE technical partners were all available to attend them.

Figure 1 shows part of the ART-SCENE scenario for *VA2 Approach and arrival sequence control*. Typical events included *dispatcher communicates with ramp staff* and *BCA approach controller makes decisions about landing approach*. Each *scenario workshop walkthrough* took place in a meeting room with one facilitator and one scribe. Each was designed to run for 2-4 hours, depending on the number of events in the scenario.

The one scenario in which aircraft do not move was more amenable to walk through in the workplace. The *VA4 On-stand operations scenario* specifies all behaviour related to the turnaround of an aircraft from when it parks to its pushback. Part of the scenario is shown in Figure 2. Typical events included *refuel the aircraft* and *disembark passengers*. The walk through of this scenario took place over 4 hours on a weekday. The analyst who facilitated the *scenario workshop walkthroughs* also facilitated the *scenario workplace walkthrough*. A different scribe operated the MSP. The facilitator observed on-stand operations on different aircraft turned around by airlines and the local service operator. He asked questions to airport and airline staff being observed. All spoken requirements and comments were recorded in the MSP.

Figure 3 shows the facilitator and scribe walking through the scenario in the workplace. The left-hand side depicts the scribe in the cockpit of an A321 aircraft whilst the facilitator asked questions about ground system-aircraft uploads, whilst the right-hand side shows the facilitator asking questions of the operator during aircraft refueling. Note the bad weather!

Figure 3. Two uses of the MSP when walking through the *VA4 On-stand operations* scenario in the workplace.

4.2 Generating the Scenarios

In VANTAGE we generated one scenario for each of the 5 prioritized use cases. Each scenario normal course event sequence specified the expected event ordering during aircraft approach, landing, taxiing, turnaround and takeoff. For each normal course event in the 5 scenarios the algorithm generated one or more candidate alternative courses for each normal course event. Alternative courses were generated using the domain-independent version of the ART-SCENE algorithm [Maiden 2004] not tailored to air traffic control. VANTAGE scenario alternative courses expressed abnormal behaviours and states that were domain-independent, such as *what if the dispatcher lacks the necessary knowledge?* and *what if the aircraft exhibits some abnormal behaviour?*, rather than *what if the air-*

craft uses the wrong taxiway when arriving at the terminal? A generated scenario specified on average 20 normal course events and 8 alternative course events per normal course event. The shortest scenario was *VA11 Coordinate flight schedules* with 8 normal course and 41 alternative course events. The longest was *VA4 On-stand operations* with 35 normal course and 271 alternative course events.

4.3 Scenario Walkthrough Results

All scenario walkthroughs took place as planned. Each *scenario workshop walkthrough* lasted between 2 and 4 hours. The *scenario workplace walkthrough* lasted 4 hours. Between 6 and 10 stakeholders attended each workshop depending on availability – commercial airline pilots and air traffic controllers were often unable to commit time to *scenario workshop walkthroughs*, hence the workshop schedule was a compromise between stakeholder availability and deadlines. Nonetheless all 4 included at least one representative from BCA (e.g. *an air traffic controller*), an airline (e.g. *a BMI dispatcher and pilot*), a solution technology provider (e.g. *Thales and Raytheon*), and an environmental researcher from an academic partner in VANTAGE. Many stakeholders participated in more than one *scenario workshop walkthrough*.

Results from the scenario walkthroughs are reported in Table 3. The five walkthroughs generated 147 requirements. All requirements were documented in ART-SCENE using four attributes – the requirement description, rationale, type and source [Robertson & Robertson 1999]. During *scenario workshop walkthroughs* the scribe entered these fields using a desktop computer keyboard, whilst during the *scenario workplace walkthrough* the scribe selected the requirement type from a pull-down menu, then the facilitator recorded the spoken requirement description, rationale and source in the MSP. After the walkthrough the facilitator and scribe transcribed all spoken requirements, comments and scenario changes, then the documented requirements were validated with source stakeholders. In the *scenario workshop walkthroughs* the stakeholders were able to validate requirements as the scribe entered them into the displayed ART-SCENE requirements form.

Scenario and walkthrough type	Total number of requirements documented	Number of requirements on use case and normal course event behaviour	Number of requirements on alternative course behaviour	Average number of requirements per normal course event
VA2: Approach and arrival sequence control (Workshop)	32	30	2	1.19
VA3: Ground movement control arrivals (Workshop)	28	27	1	2.44
VA1: Ground movement control departure (Workshop)	16	15	1	0.70
VA11: Coordinate flight departures (Workshop)	12	12	0	1.5
VA4: On-stand operations (Workplace)	59	59	0	1.55
Total	**147**	**143**	**4**	

Table 3. The total number of requirements documented during each scenario, types of event for which requirements were documented, and average number of requirements generated per scenario normal course event, in the VANTAGE project.

Results reveal that walking through *VA4 On-stand operations* in the workplace generated 59 requirements, whilst the most requirements generated during one *scenario workshop walkthrough* was 32, for *VA2 Approach and arrival sequence control*. Each *scenario workshop walkthrough* generated on average 22 requirements per scenario. The average number of requirements generated per scenario normal course event is also reported in Table 3, but there was no discernible association between scenario length and the number of requirements generated.

Alternative course events appeared to have little effect on requirements discovery – only 4 requirements were associated with alternative course events in the 5 scenarios. One possible reason for this was the number of normal course events in each scenario and limited time available in each walkthrough. Each *scenario workshop walkthrough* walked through the normal course events before the alternative course events. In most walkthroughs the time available allowed stakeholders to walk through all normal course events but not most alternative course ones.

Previous studies revealed that requirements documented with the MSP and stylus were shorter than requirements documented via keyboards [Maiden et al. 2006]. In VANTAGE, requirements transcribed from the recordings of the spoken requirements in the MSP were similar in length to requirements typed by the scribe in the 4 *scenario workshop walkthroughs*.

Table 4 reports the totals of requirement generated by type. Walking through the scenario in the workplace led to generation of more availability- and usability-type requirements than during the *scenario workshop walkthroughs*.

Scenario and walkthrough type	AR	FR	LFR	IR	PR	RR	SR	TR	UR
VA2 (Workshop)	0	17	0	0	8	0	1	0	2
VA3 (Workshop)	0	10	0	0	6	0	0	0	0
VA1 (Workshop)	1	26	0	0	2	2	0	0	1
VA11 (Workshop)	0	10	0	0	1	0	0	0	1
VA4 (Workplace)	9	28	0	1	6	1	0	1	13

Table 4. The total number of requirements documented during each scenario by type. AR=availability; FR=functional; LFR=look-and-feel; IR=inter-operability; PR=performance; RR=reliability; SR=safety; TR=training; UR=usability

Occasionally the walkthroughs resulted in changes to the scenarios themselves in response to stakeholder comments and facilitator observations. The *scenario workplace walkthrough* of *VA4 On-stand operations* resulted in 11 changes, including the addition of 2 observed new normal course events (e.g. *the engineer enters the aircraft*) and 9 observed alternative course events, for example *what if the stand is occupied?* In contrast the 4 *scenario workshop walkthroughs* resulted in just one change – an event is undertaken by an *air traffic support assistant* rather than a *controller.*

4.4 Qualitative Requirements Analysis

We investigated all 147 requirements to detect qualitative differences between requirements associated with the 2 types of scenario walkthrough.

4.4.1 Requirements Subjects

The first characteristic was the subject of each requirement. ART-SCENE mandated that all requirements were expressed using *shall* statements with a common structure [Alexander & Stevens 2002] that leads to specification of properties of one or more actors. These actors were the subjects of the requirements. Results are reported in Table 5. Most requirements generated during the *scenario workshop walkthroughs* were requirements on the VANTAGE software system. In contrast the *VA4 On-stand operations scenario workplace walkthrough* generated 20 requirements on the *dispatcher* and 12 on the *dispatch coordinator*, both actors in on-stand activities observed by the facilitator and scribe. And yet the 4 *scenario workshop walkthroughs* only generated a total of 6 requirements on the dispatcher, in spite of the presence of dispatchers in each. This indicates that the type of the scenario walkthrough, rather than dispatcher availability, influenced the generation of these 20 requirements.

Requirement subject actor	Scenario workshop walkthroughs				Scenario workplace walkthrough
	VA2	VA3	VA1	VA11	VA4
ATCO	3	1	7	2	0
BCA	0	0	0	0	3
VANTAGE system	14	8	16	4	19
Dispatcher	1	2	2	1	20
Ramp staff	2	1	2	1	1
Support services staff	2	0	0	0	0
Customer services agent	1	0	0	0	1
Dispatch coordinator	0	0	0	0	12
Pilot / Aircraft	2	0	1	0	1
Airline	0	0	3	0	0
Airport operations staff	1	3	1	3	0
Passengers/general public	1	0	0	0	2
Stand guidance system	0	1	0	0	0
Other	1	0	0	0	0

Table 5. Totals of requirements with subject actor, generated per VANTAGE scenario walkthrough.

The 12 requirements on the *dispatch coordinator* were important in VANTAGE. In spite of earlier modeling of airport operations with *i*,* the focus on dispatchers working for airlines such as BMI rather than the airport services operator led the project to overlook the dispatch coordinator. As a result the *scenario workshop walkthroughs* did not include representatives of the air services operator, and no requirements on the *dispatch coordinator* were generated. In contrast, the walkthrough of one aircraft turnaround scenario in the workplace took place in front of the dispatch coordination office. After asking about the office the facilitator negotiated access to it and asked questions to the *dispatch coordinator* about their work, problems, resources and needs. Some of the 12 requirements generated for the dispatch coordinator specified the need to support effective local working practices, for example *the dispatch coordinator using VANTAGE shall maintain important information about aircraft in a stats sheet*. Other requirements revealed basic problems with airport operations that had consequences, not known beforehand to the requirements process, on environmental impact. One such problem was a lack of functioning radios that meant that dispatchers could not communicate effectively during aircraft turnarounds. The inference was that working radios would improve the efficiency of aircraft turnarounds and, as a result, contribute to aircraft movements that would reduce noise and gas emissions. The facilitator generated requirements such as *AR108 dispatchers, the dispatch coordinator the boarding staff shall have sufficient communication resources to enable two-way communication between these actors at all times*.

4.4.2 Requirements Themes

A second characteristic was the theme of each requirement. The *scenario workplace walkthroughs* generated requirements with themes that were not generated during the *scenario workshop walkthroughs*. Fourteen requirements specified how VANTAGE should respond to bad weather conditions. The walkthrough took place in bad weather conditions depicted in Figure 3. During a follow-up interview the conditions prompted the facilitator to ask how they affected aircraft turnaround. One dispatcher provided paper documentation that specified bad weather restrictions on turnaround equipment use, from which the facilitator generated requirements such as *AR112 the VANTAGE system shall support airport operations in all possible adverse weather conditions that can arise at BCA* and *FR250 the VANTAGE system shall recognize the maximum operable wind speed of 50 knots for stand parking of the A320/1 aircraft*.

The *scenario workplace walkthrough* revealed another theme – that dispatch work was highly mobile – which led the facilitator to ask about requirements about mobile working. One dispatcher reported previous experiences with mobile tools at the nearby Belfast International Airport that revealed an opportunity for mobile computing for dispatchers at BCA. An example availability requirement was *AR111 the VANTAGE system shall connect with different mobile computing platforms* *at all airside locations*. Again, dispatchers in the *scenario workshop walkthroughs* did not generate requirements on this theme.

4.4.3 Physical Features in Requirements

A third characteristic was description of geographical and physical features of the airport in each requirement. We might expect the *scenario workplace walkthrough* (in which the analyst moves about the airport) to include more references to geographical and physical features than requirements generated during the workshops. Table 6 reports the totals of requirements that described geographic features by scenario. Not surprisingly scenario *VA4 On-stand Operations*, which was walked through in the workplace, generated the largest number of such requirements. Some requirements make reference to the complexities of taxiing and parking that emerges from the topological layout of the airport, for example *FR363 The VANTAGE system shall include rules which incorporate the specification of stands* and *FR369 The BCA tower ATCO shall have access to information about the optimum taxi route to allocated stand based on aircraft type and loading*. The walkthrough generated all of the requirements that described air bridges, dispatch offices and departure gates, for example *AR106 BCA shall have sufficient airside staff on duty at any one time to stand behind an aircraft and stop road traffic during its pushback*. The *scenario workshop walkthroughs* did not generate requirements describing the airport geography in the same level of detail.

Requirement geographic reference	Scenario workshop walkthroughs				Scenario workplace walkthrough
	VA2	VA3	VA1	VA11	VA4
Stand	8	11	3	1	7
Air bridge	0	0	0	0	2
Air side	0	0	0	1	8
Dispatch office	0	0	0	0	2
Departure gate	0	0	0	0	4
Road way	0	0	0	0	1

Table 6. Totals of requirements that reference geographic features, generated per VANTAGE scenario walkthrough.

4.5 The Scenario Workplace Walkthrough

The facilitator and scribe adapted the *VA4 On-stand Operations* scenario walkthrough to the workplace. It was difficult to observe one aircraft turnaround from start to end because more than one aircraft turned around at the same time. Furthermore event timings and action durations were unpredictable. Some scenario events related to a single aircraft were simultaneous and described concurrent actions that were difficult to observe, for example *ramp staff insert chocks*, *passenger steps* and *plug-in the aircraft to ground power* at the same time. Others actions lasted a long time but revealed little to observe, for example *the crew clean the aircraft*. Therefore the facilitator and scribe walked through selected scenario events with one aircraft before jumping to other scenario events with another aircraft.

4.5.1 What Triggered Requirements Generation

During the walkthrough the facilitator recognized more event triggers to generate new requirements from the workplace than from scenario events presented on the MSP. For example requirement FR235 *The dispatcher shall be able to see and hear refueling activities on the aircraft for which the dispatcher is responsible* was generated in response to observations of a dispatcher's reaction to the (loud) sound of the refueling truck stopping when refueling stopped. We identified 3 possible reasons for this dominance of workplace triggers. One was the richness of the triggers in a complex and dynamic workplace such as an airport. The facilitator was an experienced analyst who drew on his experience to ask requirements discovery questions in response to observed events that he knew the VANTAGE system needed to respond to. A second reason was the small screen size of the MSP. It was difficult for the facilitator and scribe to read the MSP scenario at the same time. Therefore, during the walkthrough, the facilitator and scribe developed a workaround. The scribe would read out recognized events – typically alternative course events – then the facilitator would investigate these events as he was able. However, this workaround meant that the more experienced facilitator could not browse and recognize scenario events directly. A third possible reason was the mismatch between the large number of alternative course events generated in the scenario and browsed in the MSP, and the relatively small number of real-world events that might conceivably happen in the airport environment. The effort needed by the scribe to scroll and read alternative course events in the MSP was greater than that needed to observe the workplace. Hence the facilitator took the simpler option during the walkthrough.

4.5.2 How Requirements Were Documented

The procedure with which the facilitator specified requirements also varied. In response to some events the facilitator was able to document a requirement at the time of the scenario event using information gathered from short interactions with observed stakeholders. For example the requirement *AR105 BCA shall have sufficient airside staff on duty at any one time not to delay the off-block time of departing aircraft* was generated in response to asking a dispatcher why she had to stand next to aircraft during pushback, and what would happen if she did not do it – an interaction of no more than 20 seconds.

Other requirements could not be specified during the scenario event because the event was too short, dangerous or difficult, so the scribe marked the events to follow up when relevant stakeholders were available. Between observations of scenario events, the facilitator conducted structured interviews, sometimes lasting as long as 10 minutes, with stakeholders to discuss observed events and document stakeholder requirements. All were audio-recorded in full using the MSP. For example, an interview with an experienced dispatcher led to requirement *TR76 All dispatchers who dispatch aircraft that load passengers using the air bridge shall be trained to use aircraft cockpit instructions to inform themselves of refueling status…* based on observations of a busy dispatcher entering the aircraft cockpit whilst embarking passengers. In one case – when exploring requirements for dispatcher mobile working – the facilitator prompted a mini-brainstorm, using the PDA on which the MSP was running, to demonstrate possible uses.

4.5.3 Scenario Walkthrough Productivity

The VANTAGE scenario walkthroughs consumed airport and airline resources including pilots and air traffic controllers. Therefore we computed the estimates of stakeholder time needed to generate a requirement in each *scenario workshop walkthrough* and the *scenario workplace walkthrough*. On average each of the 4 *scenario workshop walkthroughs* involved 8 stakeholders, lasted 2.5 hours and generated 22 requirements. From this data we compute that 1.1 requirements were generated per hour of stakeholder participation. Stakeholder involvement in the *scenario workplace walkthrough* was more difficult to estimate. The walkthrough timetable was reviewed to reveal that the walkthrough consumed approximately 7.2 person-hours, including 5 hours of time from the BCA environmental manager who acted as a chaperone for the walkthrough. The *scenario workplace walkthrough* generated 59 requirements. From this data we compute that 8.2 requirements were generated per hour of stakeholder involvement. The estimates, although crude, do suggest that the VANTAGE *scenario workplace walkthrough* was more productive in terms of stakeholder time.

5. Walking Through Scenarios in APOSDLE

We also walked through ART-SCENE scenarios to discover requirements for APOSDLE, a system to support work-integrated learning by knowledge workers such as aeronautic engineers, systems developers and consultants working for chambers of commerce in Germany. The four-year project, funded by the European Commission, included application partners from the aerospace multinational EADS, a German software development organization called CNM, a business consultancy called ISN, and IHK, the Darmstadt Chamber of Commerce.

Again we walked stakeholders through scenarios as part of the RESCUE scenario-driven requirements process [Maiden et al. 2004]. Prior to the walkthroughs the requirements team had discovered requirements on the new APOSDLE system using a creativity workshop and pair-wise use case authoring. A use case model specified 15 core use cases that specified how the future APOSDLE-enhanced work-integrated learning should take place at different organizations. Requirements on APOSDLE were associated with behaviour specified in the use cases. However, again, we still needed APOSDLE stakeholders to discover complete requirements on APOSDLE using projections of its future use with scenario walkthroughs.

5.1 The Scenario Walkthrough Schedule

APOSDLE stakeholders prioritized use cases for their potential impact on work-integrated learning. The workshop walkthrough schedule is reported in Table 7. ART-SCENE was used to generate one scenario for each of the selected 8 use cases. These 8 scenarios were walked through once in a *scenario workshop walkthrough* that was attended by application and technology partners from different stakeholder partners. Selected scenarios were then walked through again using the MSP with *scenario workplace walkthroughs* at 2 application partner sites – ISN and CNM. Six such *scenario workplace walkthroughs* took place. Several scenarios, such as *AP24 Use learning event* and *AP12 Collaborate*, were therefore walked through 3 times – once in a workshop and twice in the workplace at 2 application partner sites.

Date	Scenario	Type of walkthrough
30/04/07	AP8: Monitor work context	Workshop
01/05/07	AP24: Use learning event	Workshop
01/05/07	AP4a: Find and contact relevant knowledge workers	Workshop
02/05/07	AP9b: Store information exchanged	Workshop
02/05/07	AP12: Collaborate	Workshop
03/05/07	AP6: Make relevant knowledge artefact relevant to APOSDLE tools	Workshop
04/05/07	AP22: Trigger learning	Workshop
04/05/07	AP23: Construct and select learning event	Workshop
10/05/07	AP24: Use learning event	Workplace at ISN
10/05/07	AP12: Collaborate	Workplace at ISN
16/05/07	AP12: Collaborate	Workplace at CNM
16/05/07	AP4a: Find and contact relevant knowledge workers	Workplace at CNM
16/05/07	AP8 Monitor work context	Workplace at CNM
16/05/07	AP24: Use learning event	Workplace at CNM

Table 7. The APOSDLE scenario walkthrough schedule.

Figure 4 shows part of the ART-SCENE scenario for *AP24 Use learning event* used in one of the *scenario workshop walkthroughs*. Typical events included *the learning event is shown to the user* and *the user clicks on the search refinement button*. Each of the 8 *scenario workshop walkthroughs* took place in a meeting room with one facilitator, one scribe who controlled ART-SCENE and a second scribe who provided access to previous creativity workshop results that were also displayed on a large screen. The facilitator and stakeholders interacted directly with the APOSDLE prototype displayed on an electronic whiteboard through the touch screen. Each *scenario workshop walkthrough* was designed to run for 2-4 hours, depending on the number of events in the scenario. Figure 5 shows a facilitator interacting with and annotating the software prototype during requirements discovery, and stakeholders during the workshop surrounded by design prompts from creativity workshop outcomes.

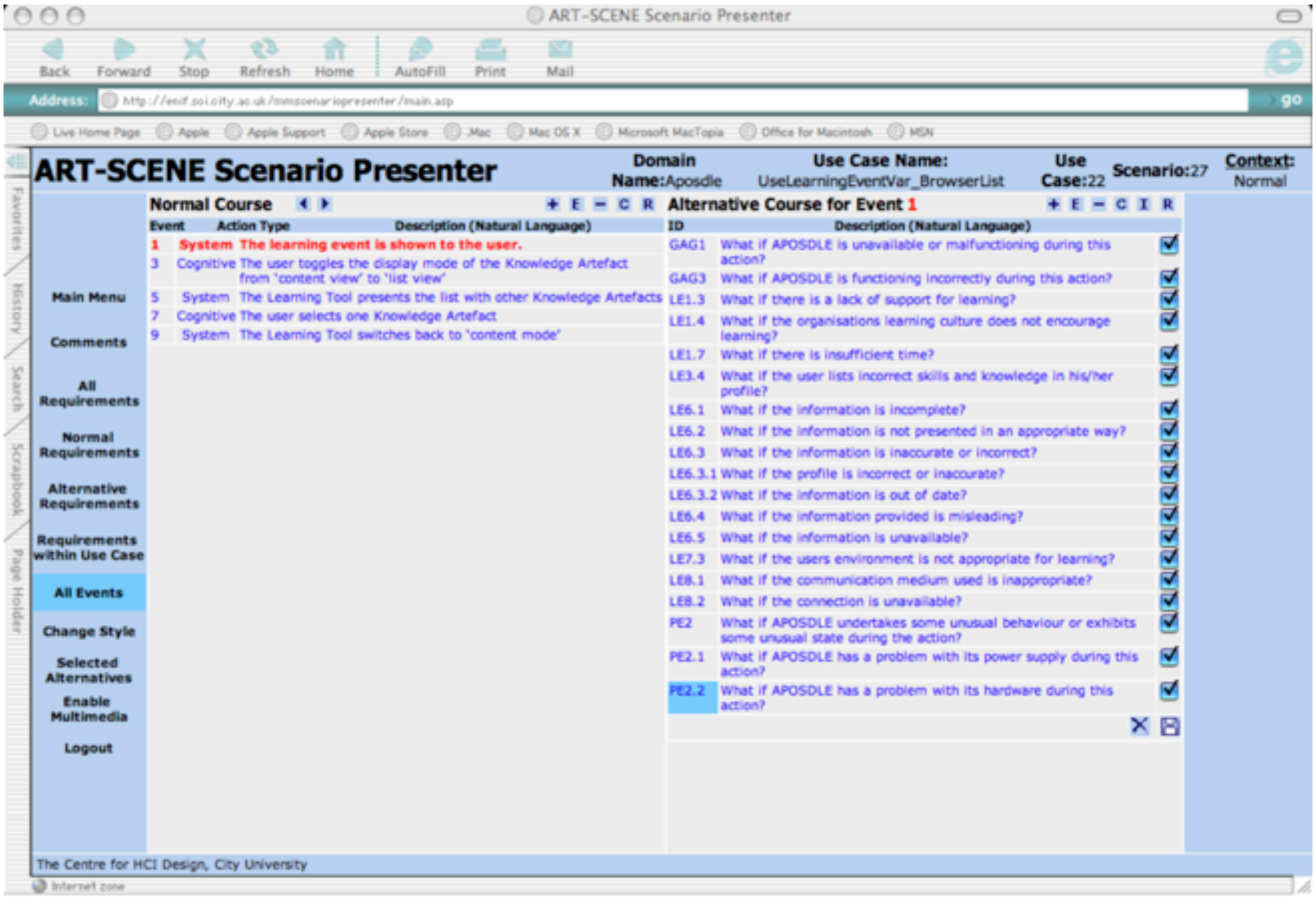

Figure 4. One variation of the APOSDLE scenario (*AP24 Use Learning Event*) in the desktop version of ART-SCENE used during one *scenario workshop walkthrough*

Figure 5. Images from one APOSDLE *scenario workshop walkthrough*, the left-hand side showing annotation of software prototypes on an electronic whiteboard, the right-hand side showing stakeholders surrounded by outputs from the earlier creativity workshop.

The 6 *scenario workshop walkthroughs* took place over 2 days at the sites of 2 APOSDLE application partners in Germany and Austria. One analyst, a native German speaker who had not been present in the *scenario workshop walkthroughs*, facilitated the *scenario workplace walkthroughs*. A different scribe, also a German speaker, operated the MSP. The facilitator observed work-based learning behaviour and asked questions to staff being observed. All spoken requirements and comments were recorded in text and audio form in the MSP. Figure 6 shows the *scenario workplace walkthrough* at the consultancy company ISN in Graz, Austria.

Figure 7. An APOSDLE *scenario workplace walkthrough*, showing the use of the MSP at consultancy organization ISN.

5.2 Generating the Scenarios

Each generated scenario normal course specified the expected order of events during APOSDLE's generation, use and management of learning material. For each normal course event in the 8 scenarios, the algorithm generated one or more candidate alternative courses for each normal course event. This time alternative courses were generated using the domain-independent ART-SCENE algorithm [Maiden 2004] extended with a domain-specific version that included class hierarchies of abnormal behaviour and state derived from published learning literature. Domain-independent alternative courses included *what if the knowledge worker lacks the necessary knowledge?* and *what if the expert exhibits some abnormal behaviour?* Domain-dependent alternative courses included *what if the user's environment is inappropriate for learning?* and *what if the communication medium used is inappropriate?* Other examples are shown on the right-hand side of Figure 4. Each generated scenario specified on average 13 normal course events and 19 alternative course events per normal course event. The shortest scenario was *AP6: Make relevant knowledge artefact relevant to APOSDLE tools* with 5 normal course and a total of 78 alternative course events. The longest was *AP24 Use learning event* with 19 normal course and a total of 457 alternative course events in the principal normal course and four variation scenarios

5.3 Scenario Walkthrough Results

All scenario walkthroughs took place as planned. Each of the 8 *scenario workshop walkthroughs* lasted between 2 and 4 hours. Between 3 and 8 technology and end-user stakeholders attended each workshop, and each included at least one technology partner and one application partner. The 6 *scenario workplace walkthroughs* lasted a total of about 10 hours not including time taken for tool setup and coffee breaks. The mobile analysts observed and interacted with end-users from the application partners rather than the technology developers.

Results from the scenario walkthroughs are reported in Table 8. The 8 *scenario workshop walkthroughs* generated 228 requirements that included 46 requirements for *AP24 Use learning event.* The average number of requirements generated per *scenario workshop walkthrough* was 28.5. As in VANTAGE these requirements were documented using ART-SCENE. *Scenario workplace walkthroughs* generated 160 requirements generated mostly during walkthroughs of scenarios *AP12* and *AP24.* The *scenario workplace walkthroughs* at ISN in Graz discovered 52 requirements for *AP12* and *19* requirements for *AP24.* At CNM in Dortmund the *scenario workplace walkthroughs* generated 24 requirements for *AP12* and 36 requirements for *AP24.* Additionally, at CNM we gathered requirements for 2 other scenarios, which were not the focus of the inquiry, so less time was spent walking through them. The average number of requirements generated per *scenario workplace walkthrough* was 26.7.

Scenario and	Total number of	Number of re-	Number of re-	Average number

walkthrough type	requirements documented	quirements on use case and normal course event behaviour	quirements on alternative course behaviour	of requirements per normal course event
AP8: Monitor work context (Workshop)	36	25	11	4.0
AP24: Use learning event (Workshop)	46	32	14	2.0
AP4a: Find and contact relevant knowledge workers (Workshop)	30	28	2	3.0
AP9b: Store information exchanged (Workshop)	32	20	12	4.0
AP12: Collaborate (Workshop)	20	16	4	1.82
AP6: Make relevant knowledge artefact relevant to APOSDLE tools (Workshop)	10	10	0	2.0
AP22: Trigger learning (Workshop)	22	18	4	0.81
AP23: Construct and select learning event (Workshop)	32	27	5	4.57
AP12: Collaborate (Workplace at ISN)	52	44	8	2.73
AP24: Use learning event (Workplace at ISN)	19	13	6	1.72
AP12: Collaborate (Workplace at CNM)	24	21	3	2.18
AP4a: Find and contact relevant	7	5	2	0.7

knowledge workers (Work-place at CNM)				
AP8 Monitor work context (Workplace at CNM)	22	20	2	2.75
AP24: Use learn-ing event (Workplace at CNM)	36	30	6	1.89
Total	**388**	**309**	**79**	

Table 8. The total number of requirements documented during each scenario, types of event for which requirements were documented, and average number of requirements generated per scenario normal course event, for the APOSDLE project.

Requirements were again analyzed by type as reported in Table 9. Results revealed that, unlike VANTAGE, the *scenario workshop walkthroughs* generated more usability-, performance- and main-tainability-type requirements than did the *scenario workplace walkthroughs*. In contrast the *scenario workplace walkthroughs* generated 18 security-type and 11 interoperability-type requirements, in contrast to low numbers of these requirement type generated in the *scenario workshop walkthroughs*. However no overall pattern of requirement generation by type emerged.

	Sce-nario	AR	FR	LFR	IR	PR	RR	SR	TR	UR	BUS	LG	MR	DR
Scenario workshop walkthroughs	AP8	0	23	0	1	2	1	0	0	4	2	1	2	0
	AP4	0	26	1	0	0	0	0	0	15	3	0	0	1
	AP4a	0	30	0	0	0	0	0	0	0	0	0	0	0
	AP9	0	29	0	0	0	0	0	0	2	0	0	1	0
	AP12	0	18	0	1	0	0	0	1	0	0	0	0	0
	AP6	0	7	0	0	0	0	0	0	3	0	0	0	0
	AP22	0	14	0	0	2	0	0	0	5	0	0	1	0
	AP23	0	18	0	0	0	1	0	0	12	0	0	1	0
Scenario workplace walkthroughs at ISN	AP24	0	17	0	0	0	0	2	0	0	0	0	0	0
	AP12	0	28	0	7	0	2	5	1	2	7	0	0	0
Scenario workplace walkthroughs	AP12	0	14	0	3	0	0	5	0	0	2	0	0	0
	AP4a	0	6	0	0	0	0	0	0	0	1	0	0	0
	AP8	0	13	0	0	0	0	6	0	1	1	1	0	0

at CNM	AP24	0	28	0	1	0	0	0	0	1	6	0	0	0

Table 9. The total number of requirements documented during each scenario by scenario walkthrough type. AR=availability; FR=functional; LFR=look-and-feel; IR=inter-operability; PR=performance; RR=reliability; SR=safety; TR=training; UR=usability; BUS=business goals; LG=legal; MR=maintainability; DR=Device

Although most of the 228 requirements generated in the *scenario workshop walkthroughs* were expressed in text form, the screen capture capability of the electronic whiteboard enabled the facilitator and stakeholders to annotate and save images of the software prototype associated with these requirements. 14 of these 228 (6.1%) APOSDLE requirements were documented in this manner. Figure 7 shows 3 examples of these enhanced requirement descriptions.

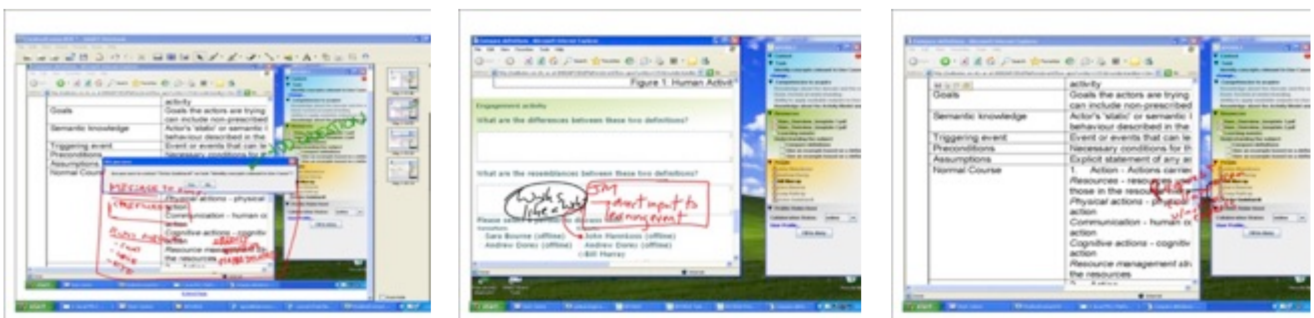

Figure 7. Three APOSDLE screen shots taken from requirements discovered during the *AP12 Collaborate*, *AP24 Use learning event* and *AP4a Find and contact relevant knowledge workers scenario workshop walkthroughs*.

The 6 *scenario workplace walkthroughs* generated a total of 58 observations (an average of 9.67 per scenario) recorded as comments. Of these 58 comments, 31 were documented for *AP12 Collaborate* at the CNM site where observation time was significantly higher than the time spent interviewing stakeholders during the walkthroughs.

5.4 Qualitative Requirements Analysis

We investigated the APOSDLE requirements to detect qualitative differences between requirements based on requirement subject, theme and inclusion of physical features generated with the different types of scenario walkthrough. To enable this investigation we first analyzed the requirements to remove duplicates that arose from walking through the same scenario multiple times with different stakeholders. Of the 160 requirements generated during *scenario workplace walkthroughs*, 22 had already been specified once before in a walkthrough and 1 had been specified twice before. Of the 22 duplicated requirements, 12 had been originally specified in *scenario workshop walkthroughs* and 10 in *scenario workplace walkthroughs.* The removal of these 24 repeating requirements resulted in a total of 364 unique APOSDLE requirements that were investigated for their subjects, themes and description of physical features in the work context.

5.4.1 Requirements Subjects

The first characteristic was the subject of each requirement. As in VANTAGE, ART-SCENE mandated that all requirements were expressed using *shall* statements with a common structure [Alexander & Stevens 2002] that highlighted the subjects of requirements as the actor upon which the requirement was specified. Results are reported in Table 10. Most requirements were on the APOSDLE system and its users independent of the type of walkthrough that generated them (e.g., *The APOSDLE system shall generate a learning goal from the user question*). Compared to VANTAGE, there were fewer differences regarding requirement subjects between *scenario workshop walkthroughs* and *scenario workplace walkthroughs*. The *scenario workplace walkthroughs* generated requirements on the learner, collaboration transcript and collaboration document not generated in the *scenario workshop walkthroughs*.

Requirements subject actor	Scenario workshops walkthroughs							Scenario workplace walkthroughs at ISN		Scenario workplace walkthroughs at CNM			
	AP8	AP24	AP4a	AP9	AP12	AP6	AP22	AP12	AP24	AP12	AP4a	AP8	AP24
APOSDLE system	22	32	18	12	8	7	20	26	8	14	4	18	23
Collaboration participant	0	0	0	3	1	0	0	5	0	1	0	0	0
User	12	13	6	17	8	3	2	8	2	1	0	1	9
Expert	0	1	6	0	1	0	0	0	0	0	1	0	0
Collaboration Transcript	0	0	0	0	0	0	0	3	0	0	0	0	0
Collaboration Document	0	0	0	0	0	0	0	3	0	0	0	0	0
Learner	0	0	0	0	0	0	0	2	6	0	0	0	0

Customer	0	0	0	0	0	0	0	0	0	1	0	0	0
Administrator	1	0	0	0	0	0	0	0	0	0	0	0	0
Collaboration Tool	0	0	0	0	2	0	0	0	0	0	0	0	0
Knowledge Engineer	1	0	0	0	0	0	0	0	0	0	0	0	0

Table 10. Totals of requirements with different subject actors, generated per APOSDLE scenario walkthrough

5.4.2 Requirements Themes

A second characteristic was the theme of each requirement reported in Table 11. There was one main requirement theme generated during the *scenario workplace walkthroughs* – privacy. Although 8 requirements with this theme had been generated in *scenario workshop walkthroughs*, the *scenario workplace walkthroughs* generated 17 additional privacy-type requirements such as *the APOSDLE system shall delete context monitoring history after a short time*. However, compared to the VANTAGE project, there were fewer differences in the themes of requirements generated in the *scenario workshop walkthroughs* and *scenario workplace walkthroughs*.

Requirements themes	Scenario walkthrough workshops							Scenario workplace walkthroughs at ISN		Scenario workplace walkthroughs at CNM			
	AP8	AP24	AP4a	AP9	AP12	AP6	AP22	AP12	AP24	AP12	AP4a	AP8	AP24
APOSDLE affect on users	4	3	0	0	0	0	4	8	0	0	1	1	2
APOSDLE affect on current work practices	2	3	0	0	0	0	1	4	0	0	0	1	2
APOSDLE support for mobility	0	2	0	0	0	0	0	3	0	0	0	0	0
APOSDLE user profile	2	0	9	2	1	0	5	0	1	0	1	0	2
Knowledge artefact	1	10	0	19	2	4	0	5	0	0	0	0	0
Context monitoring	14	0	0	0	1	0	1	2	0	1	0	4	0
Privacy issues	2	1	1	3	1	0	0	6	2	4	0	5	0

Create knowledge artefact	1	1	0	3	3	0	1	4	1	7	0	5	1
Availability for collaboration	0	1	4	0	0	0	0	2	7	0	3	3	0
Learning process	4	23	0	0	1	5	9	3	4	0	0	0	24
Collaboration process	0	2	16	3	10	0	0	7	0	5	0	0	0
Other	0	0	0	0	0	1	0	3	1	0	0	0	1
System admin-istration	4	0	0	2	1	0	1	0	0	0	0	0	0

Table 11. Totals of requirements by requirements themes, generated per APOSDLE scenario walkthrough.

5.4.3 Physical Features in Requirements

The third characteristic was the description of physical features of the ISN and CNM office in each requirement. In contrast to the VANTAGE project, we did not discover requirements that referred to any physical features. One possible reason is that physical features are less important for a desktop based learning support system than for an airport management system.

5.5 Scenario Walkthrough Productivity

Again we computed the estimates of APOSDLE stakeholder time needed to generate a requirement in a *scenario workshop walkthrough* and a *scenario workplace walkthrough.* On average each of the 7 workshops involved 3.9 stakeholders (not including facilitator and scribe), lasted 2.45 hours and generated 28.4 requirements. From this data we compute almost 3.0 requirements were generated per hour of stakeholder participation, which was higher than the rate of generation during the 4 VANTAGE *scenario workshop walkthroughs*.

Calculating stakeholder time spent on the APOSDLE *scenario workplace walkthroughs* was again more difficult. At ISN stakeholders participated in walkthroughs that lasted a total of 3.8 hours. We generated 71 requirements including the 8 duplicate ones. Both analysts interacted with the stakeholders for 2.8 hours – the remainder of the time was spent observing them. From this data, we computed 13.2 requirements were generated per hour of stakeholder participation, higher than the rate of the VANTAGE *scenario workplace walkthroughs*. At CNM we spent 3.2 hours (55%) on interactions with stakeholders, while 2.6 hours (45%) were spent on observations. During the *scenario workplace walkthroughs* at CNM 89 requirements were generated (73 without duplicates). We computed that 17.7 requirements were generated per hour of stakeholder participation, again a rate higher than the VANTAGE *scenario workplace walkthroughs*.

Furthermore, on average, the *scenario workshop walkthroughs* generated 5.8 requirements per hour of analyst and scribe participation. *Scenario workplace walkthroughs* at ISN generated 8.3 requirements per hour of analyst participation. Due to the increased observation time at CNM the *scenario workplace walkthrough* generated 6.2 requirements per hour.

5.6 The Scenario Workplace Walkthroughs

Most tasks that were walked through in the workplace were standard office tasks (e.g., checking e-mail) that could be mapped to scenario normal course events. As a consequence analysts were able to interrupt stakeholders to ask questions as well as ask follow-up questions after uninterruptible tasks (e.g., talking to a customer on the phone). The facilitator and scribe rotated the roles to increase their chances of recognizing cues provided by the MSP. Over time both became familiar with the scenarios, which reduced time to navigate them.

5.6.1 What Triggered Requirements Generation?

After the *scenario workplace walkthroughs* the 2 analysts reflected that most requirements were triggered by events in the workplace, for 2 reasons. The first was that, during APOSDLE, both the analyst and scribe were equipped with the MSP tool, which allowed them to read the scenarios at the same time. The second was that the office environment was simpler, less dynamic and therefore provided fewer triggers than the airport environment.

5.6.2 How Requirements Were Documented

In contrast to VANTAGE most requirements were documented in text rather than audio form using the MSP stylus and keyboard. One reason was that, because the analyst and scribe were equipped with PDAs, there was no need to communicate scenario information to the facilitator, which in turn gave more freedom to the scribe. The less dynamic and mobile office environment also gave the analysts more time to type requirements into the MSP, a luxury not available in previous *scenario workplace walkthroughs* with the MSP [Maiden et al. 2006]. During one *scenario workplace walkthrough* the scribe even replaced the MSP with the desktop Scenario Presenter running on a notebook computer to document requirements due to the time available and chance to sit at a desk.

6. The Research Questions Revisited

The scenario walkthroughs in VANTAGE and APOSDLE were a success. They led to generation of 147 and 338 new requirements respectively. The use of ART-SCENE was also a success, in that we effectively applied a research prototype to two challenging requirements problems. We extended the use of the desktop Scenario Presenter in facilitated *scenario workshop walkthroughs* to support software prototype walkthroughs. The use of the MSP in VANTAGE is one of the first reported effective uses of mobile requirements tools on large projects [Maiden et al. 2007]. Simple-to-use audio recording of spoken requirements overcame the usability problems reported in [Maiden et al. 2006], whilst giving the MSP to experienced analysts realized its potential in different settings. That said, problems remained, such as difficulties encountered by two people browsing scenario events with a single MSP. We reviewed the VANTAGE and APOSDLE results to answer the 3 research questions.

6.1 Effect on Scenario Walkthroughs from a Software Prototype?

The answer to question Q1 – does a workshop walkthrough of a scenario supported with a software prototype and creativity prompts generate more requirements – is a tentative yes based on data from the *scenario workshop walkthroughs*. Not only did the APOSDLE *scenario workshop walkthroughs* with the software prototype generate more requirements per scenario – 28.5 to 26.7 – than the VANTAGE *scenario workshop walkthroughs*, but the APOSDLE scenarios were shorter. In APOSDLE 2.51 requirements were generated per normal course event, as opposed to 1.05 requirements per VANTAGE scenario. Fourteen APOSDLE requirements were supported with annotated screenshots and images not available in VANTAGE due to the absence of a prototype.

The quantitative results provide preliminary evidence that software prototypes can provide additional recognition cues with which to generate and specify new requirements. However the answer does need to be interpreted with care as other variables such as the domain, degrees of stakeholder participation and expertise, and requirements specified previously in the process clearly may all have influenced the result. Threats to validity of the findings are discussed later.

6.2 Different Requirements from Scenario Workplace Walkthroughs?

The answer to question Q2 – does walking through ART-SCENE scenarios in the workplace lead to generation of different requirements to workshops – is also a tentative yes. One *scenario workplace walkthrough* generated requirements on VANTAGE actors that the *scenario workshop walkthroughs* did not generate requirements on. It acquired requirements from new VANTAGE stakeholders not identified during earlier analyses. It acquired requirements from stakeholders who had attended the *scenario workshop walkthroughs* but not specified these requirements during them. And it generated requirements of different types on important themes not identified during the VANTAGE *scenario workshop walkthroughs*. In APOSDLE the *scenario workplace walkthroughs* at 2 different sites revealed different, potentially conflicting requirements that did not emerge clearly during the earlier *scenario workshop walkthroughs*. These walkthroughs also generated important observations not captured during the *scenario workshop walkthroughs* related to the requirements that were specified.

There are several possible reasons for these results. The first is the use of *scenario workplace walkthroughs* to do a stakeholder analysis – discovering then involving all of the important actors in VANTAGE. This was true for the dispatch coordinator role. A second possible reason was that observing the workplace enabled the facilitator to act as an apprentice and learn about actors' work, as supported in contextual inquiry [Beyer & Holtzblatt 1998]. Indeed, some periods of the *scenario workplace walkthrough* were indeed a form of ethnographic observation, albeit structured using the scenario in the MSP. This learning then enabled the facilitator to ask more informed questions during observations and structured interviews, as well as to infer more correct and complete VANTAGE requirements. In contrast the facilitator and scribe in the *scenario workshop walkthroughs* often did not have access to the domain knowledge needed to complete the specification of requirements because knowledge about the workplace was not available to them.

A third possible reason – an important one – is that the workplace provided different event recognition cues to discover requirements on different themes. Indeed, rather than trigger event recognition, the facilitator used the MSP scenario in the *scenario workplace walkthroughs* primarily to generate requirements and requirements-related data in the context of the observed normal course event. This had two important advantages. The first is that related requirements and material could be reviewed during and between walkthroughs, thus enabling the facilitator to ask more informed structured interview questions. The second is that, during post-walkthrough analyses, analysts could review the requirements and related material in context, thus providing cues to recall the observed event and more information with which to infer new requirements.

6.3 More Requirements from Scenario Workplace Walkthroughs?

The answer to question Q3 – does walking through ART-SCENE scenarios in the workplace lead to generation of more requirements than in workshops – is also a tentative yes. The one VANTAGE *scenario workplace walkthrough* generated a larger number of requirements than any single *scenario workshop walkthrough*. All VANTAGE and APOSDLE *scenario workplace walkthroughs* were more productive in terms of stakeholder time than the workshop equivalent. The repeated APOSDLE *scenario workplace walkthroughs* also generated new requirements not described in the *scenario workshop walkthroughs*.

Of course repeating walkthroughs of the same scenario in different workplaces risked the duplication of requirements that needed significant analyst effort to detect and remove. Although just over 18% of the APOSDLE requirements generated during the *scenario workplace walkthroughs* were semantic duplicates that needed to be removed from the requirements specification, over 80% of the requirements from walking through the same scenario a second or third time were new to the process, providing results with which to answer *yes* to the research question.

There are at least two possible reasons for the greater productivity of the VANTAGE scenario workplace walkthrough. The first is the role of the facilitators who, in the workplace, directly inferred and documented more requirements than in the workshops because of the limited communication that was possible with stakeholders engaged in other tasks. The outcome was that the facilitators were able to infer more requirements than they were able to acquire from stakeholders in the workshops. This has implications for redesigning the *scenario workshop walkthroughs* to enable the facilitators to infer and propose new requirements.

Conversely, a second reason is that the *scenario workplace walkthroughs* increased the requirements communication bandwidth. Whereas stakeholders did not bring written material to the workshops, the facilitators in the workplace were able to collect documents such as the bad weather operation document, as well as observe workplace artifacts such the dispatch coordinator's stats sheet and take photographs. This material added to the spoken requirements recorded in the MSP and provided a richer data corpus that the analyst used to infer larger numbers of requirements than in the workshops. Again this raises the need to design *scenario workshop walkthroughs* to encourage inference of requirements from different information sources.

6.4 Threats to Validity

We report the pragmatic use of different scenario walkthrough types to solve the VANTAGE and APOSDLE requirements problems. Our decision not to balance independent variables and control dependent ones across a low number of walkthroughs means that all results need to be interpreted with care. For example, the effectiveness of the *scenario workplace walkthroughs* could also have been influenced by the design of the walkthroughs, the stakeholder participation in them, and the reporting of the results. The VANTAGE and APOSDLE *scenario workplace walkthroughs* always occurred after the *scenario workshop walkthroughs*, hence facilitator behaviour might have been informed by domain knowledge obtained in the earlier workshop walkthroughs. The influence on stakeholders was less because, in both projects, most stakeholders observed in the *scenario workplace walkthroughs* did not participate in the *scenario workshop walkthroughs*. Implicit biases might also have risen from the desire of the facilitator and scribe to see the *scenario workplace walkthrough* succeed, especially in light of problems reported in earlier uses [Maiden et al. 2006]. However, the effort needed to set up and run the scenario walkthroughs under challenging conditions in the VANTAGE and APOSDLE projects, we believe, reduced the likelihood of such implicit bias due to the analyst's focus on more undertaking the requirements tasks making both types of walkthrough succeed to their best abilities.

7. Lessons Learned

The following lessons were learned about the design and running of scenario walkthroughs in requirements projects from our experiences in APOSDLE and VANTAGE.

The most obvious lesson is that mixing and matching different types of scenario walkthroughs, in our case scenario walkthroughs in facilitated workshops and in the workplace, generated more requirements on different actors and about different themes. In simple terms, different scenario walkthroughs increased the completeness of resulting requirements specification over sole use of one walkthrough type. A related lesson was to walkthrough the same scenarios more than once with different stakeholders. Although this led to duplicate requirements being specified, over 4 in every 5 requirements generated during the walkthroughs were original and valid. Some requirements duplication may be an acceptable price for ensuring more complete requirements specification.

One unexpected outcome of the VANTAGE *scenario workplace walkthrough* was the discovery of one new stakeholder with important requirements on the new system. It provides direct evidence for the effectiveness of *scenario workplace walkthroughs* for stakeholder analysis. Although stakeholder analysis techniques are available [e.g. Macaulay 1993], scenario workplace walkthroughs earlier in the requirements process, using simple scenarios that outline key events without exploring alternative course events, can complement existing analysis techniques and validate a current stakeholder model. Such walkthroughs earlier in the requirements process can make the scenarios more complete for later walkthroughs in workshops, as results showed that scenarios were edited and commented more frequently in the *scenario workplace walkthroughs*.

Results also provide lessons for designing scenario walkthroughs to be more effective. In particular the VANTAGE *scenario workplace walkthrough* allowed the analyst to generate new requirements that stakeholders later accepted, in strong contrast to *scenario workshop walkthroughs* in which the analyst encouraged stakeholders to generate requirements. The workshop walkthrough process has been extended to provide periods in which the analyst can propose speculative new requirements to be accepted or rejected by the stakeholders present. The *scenario workplace walkthroughs* in both projects demonstrated the value of interleaving the walkthrough with more detailed stakeholder interviews and analysis of documentation available in the workplace, although this was not part of the original walkthrough protocol. The protocol has been changed to allow for documentation collection, brainstorming and interview sessions, and guidelines given to stakeholders before *scenario workshop walkthroughs* have been extended to encourage stakeholders to bring relevant documentation to workshops.

Furthermore, results indicate that different types of scenario walkthrough with different types of stakeholders, sometimes in different workplaces, can influence the subjects and themes of the generated requirements. We recommend more a priori design of scenario walkthrough schedules that takes into account the acquisition of sets of requirements using information about the workplace and stakeholders. A requirements framework that structures requirements by subject and theme can inform the design of such a schedule.

Results from the APOSDLE *scenario workshop walkthroughs* indicated another unexpected lesson. Whilst the walkthroughs revealed weak evidence that the software prototype and creativity cues might have increased the number of requirements specified, one expected outcome was annotation of the prototype to illustrate requirements graphically using electronic whiteboards. Such illustrations can communicate requirements to stakeholders and designers more effectively, as well as lead to more requirements generation in walkthroughs.

Another lesson emerges from the productivity results. *Scenario workplace walkthroughs* were more efficient in terms of stakeholder participation time to generate requirements. If time is short, we recommend running more *scenario workplace walkthroughs* rather than *scenario workshop walkthroughs*.

One final lesson relates to the scenarios walked through in both projects. Stakeholders lacked the time needed to walk through alternative course events automatically generated by ART-SCENE. Although results do not indicate that this has led to requirements incompleteness in both projects, analysts perhaps need to specify and generate scenarios with fewer normal course events, to allow more effective walking through of the normal and alternative course events.

To conclude the lessons indicate some comparative strengths and weaknesses of *scenario workshop walkthroughs* and *scenario workplace walkthroughs* when supported with different versions of the ART-SCENE scenario environment. The next section places the strengths of *scenario workplace walkthroughs* in a wider context.

8. Related Work

Ethnographical methods have been used in requirements projects to provide an adequate understanding of the current work practice to be changed by specified systems. Several researchers used ethnographical methods to inform requirements engineering in various domains including air traffic control [Bentley et al. 1992] and underground control rooms [Heath & Luff 1992]. In some case ethnographical methods were combined with existing requirements techniques, such as viewpoints to structure the results of an ethnographic study [Hughes et al. 1995]. Viller and Sommerville [1999] reported different uses of ethnographical methods during requirements processes.

Contextual inquiry is an approach influenced by ethnography that supports system development. In contrast to other ethnographic methods, an analyst with a technical background is in charge of analyzing existing work practice [Blomberg et al. 2002, Whiteside & Wixon 2002]. Contextual inquiry is based on observation and the contextual interview, the key activity to gather design relevant data in the stakeholders' work environment. The interview is structured following the principles of contextual inquiry [Beyer and Holtzblatt 1998]. Contextual inquiry has been successfully applied in various projects in the software engineering domain [Beyer and Holtzblatt 1998]. Holtzblatt [2004] concludes that building a design upon field data was essential for the success of these projects.

Ethnographical methods and contextual inquiry support analysts' understanding of the workplace. However, problems have been highlighted [Hughes et al. 1995, Maxwell & Millard 1999, Villers & Sommerville 1999]. Most still use a paper and pencil-based approach and lack on-site tool support for guiding on-site analysts and for documenting the gathered information. Contextual inquiry techniques are only weakly integrated with existing requirements methods and tools. Moreover the volume of information gathered is often unfocused, which makes the information difficult to use in the requirements process. There is also a lack of a theoretical structure underpinning the observation process [Maxwell & Millard 1999] and due to a lack of focus these approaches are confined to relatively small-scale environments (e.g., control rooms) [Hughes et al. 1994]. The introduction of mobile tools for walking through scenarios in the workplace reported in this paper was designed to overcome some of these reported problems.

9. Future Research

Future research is in three directions. The first will extend the model of scenario-based requirements discovery with new physical tasks such as *perceive recognition cues in the work context* and *perceive possible design features*, and cognitive tasks such as *infer new requirement*, which will relate to models of creativity in requirements engineering. Secondly, we will then apply the model to redesign the scenario workshops to support analysts to infer candidate requirements and propose them to stakeholders. ART-SCENE will be extended with pattern-based requirements generation that can recommend outline requirements automatically. We will also build on existing methods (e.g. [Sutcliffe et al. 1997]) to develop new walkthrough processes, techniques and protocols to manage the effective use of scenario prototypes that provide effective additional recognition cues for discovering requirements during facilitated workshops.

Whilst MSP audio recording of spoken requirements overcame earlier usability problems, its use here revealed new challenges to solve. One is the provision of scenario event cues to both the facilitator and scribe as we explored in the reported APOSDLE walkthroughs. Screen size is dictated by available PDA devices, so one solution is to synchronize scenario walkthroughs on two devices. Whilst the scribe navigates the scenario on one device running the current MSP, a selected subset of scenario events, for example one normal course event and alternative course events associated with it, are displayed on the second device to provide the facilitator with manageable, context-specific event recognition cues. Analysts could also use this feature to select between generated alternative course events to present to the facilitator, to reduce information overload. One possible further refinement is to use context-aware devices to filter scenario events dynamically according to proximity to a location or actor. We look forward to reporting these outcomes in the near future.

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